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A Product-oriented Evaluation of Gross Motor Proficiency with 4 to 15-year-old Canadian Children

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Author Biography

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Abstract

Developing proficiency in fundamental movement skills (FMS) is necessary for games and sports, cognitive ability, psychosocial health, and daily living. The objective of this study was to investigate the gross motor development (GMD) of 589 4 to 15-year-old typically developing Canadian children using the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2). Specifically, does a sample of Canadian children fall within the established American norms? Participants were within the normal range for GMD (scale score range 11-19). However, upper limb coordination ($M = 13.5$) and balance ($M = 14.3$), failed to meet the average scale score (15). Bilateral coordination ($M = 17.1$) and running speed & agility ($M = 16.8$) showed the best results. BMI was associated with balance ($p = 0.013$), running speed & agility ($p < 0.001$) and strength ($p < 0.001$). Age was associated with all five subtests (all $p < 0.05$) and gender was not associated with any subtests. This study can serve as a baseline for other researchers studying GMD in children and youth.

Key words: Fundamental Movement Skills – Test of Motor Proficiency – Children and Youth

Résumé

Le développement d’habiletés motrices fondamentales est un élément essentiel dans plusieurs domaines tel que les jeux et les sports, les habiletés cognitives, la santé psychosociale et même dans la vie quotidienne. L’objectif de cette étude est de décrire le développement de la motricité globale d’un échantillon d’enfants canadiens à l’aide du “Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2)” et de voir si ces enfants répondent aux normes américaines reconnues. Les participants se sont classés dans l’étendue normale de ces normes de développement moteur global. Cependant le score pour la coordination des membres supérieurs et l’équilibre n’ont pas atteint la moyenne. Les scores pour la coordination bi-latérale et la vitesse et l’agilité à la course ont été les meilleurs. Une relation est présente entre l’indice de masse corporelle (IMC) et la vitesse et l’agilité à la course de même que la force. L’âge est également en relation avec les scores aux cinq tests alors que le genre n’est associé à aucun score. Cette étude peut servir de base à d’autres chercheurs intéressés par ce domaine du développement moteur global chez les enfants et les jeunes.

Mots clés: Habiletés fondamentales de movement – Test d’habileté mortice – Enfants et jeunes

Introduction

Skill proficiency in physical activities (PA) is a contributing factor to the enjoyment and pursuit of sport and an active lifestyle in childhood, persisting into adulthood (Lloyd, Saunders, Bremer, & Lloyd, 2014; Malina, 2001; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). Developing proficiency in fundamental movement skills (FMS) – the building blocks upon which children construct more complex and advanced skill patterns – is necessary not only for games and sports, but for cognitive ability (Davis, Pitchford, & Limback, 2011), psychosocial health (Lees & Hopkins, 2013), and daily living (Deforche et al., 2009). Learning these skills is influenced by the child's characteristics (morphological, physiological and neuromuscular) and the environmental opportunities and restraints experienced by the child (Malina, 2004). Children are more likely to be successful in the PA requested of them as they age, if they possess these skills (Higgs et al., 2008)

The gap between children who possess higher degrees of FMS proficiency and those who do not widens as children grow up (Hands, 2008; Wall, 2004). Low self-efficacy and perceived ability are detrimental to PA participation (Barnett, Morgan, van Beurden, & Beard, 2008), and conversely, those who perceive and demonstrate better skills tend to be more physically active (Lloyd et al., 2014). PA avoidance by lower-skilled children perpetuates a negative feedback loop as they withdraw from participation and further compromise skill development (Wall, 2004).

FMS are perhaps the most important predictor of PA in children (Bremer & Lloyd, 2014). It is possible to improve FMS with intentional instruction and free play opportunities (Logan, Robinson, Wilson, & Lucas, 2011; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), however, there is believed to be a period of optimal readiness (Higgs et al., 2008). The time taken to learn a new skill after puberty is longer than before puberty (Bayli, Way, Cardinal, Norris, & Higgs, 2008).

National statistics show that PA levels in Canadian children are inadequate (ParticipACTION, 2015). Despite physical education (PE) being part of the required school curricula, little emphasis is placed on quality and quantity of PE (Canadian Fitness & Lifestyle Research Institute, 2012), and children may not be acquiring the requisite basic motor development skills (McKenzie et al., 2001). In efforts to promote PA, numerous school- and community-based programs exist for children beginning as early as preschool. Unfortunately, the long-term effects of the intervention are not often captured (Morgan et al., 2013) and many interventions are largely ineffective at increasing PA outside of the controlled environment (Dobbins, De Corby, Robeson, Husson, & Tirilis, 2009; Kriemler et al., 2011). Criticisms of such programs include the use of non-validated measures, poor descriptions of the intervention compliance, lack of long-term follow-up, program delivery by non-PE specialists, short intervention periods (Dobbins et al., 2009; Kriemler et al., 2011) and high risk of bias (Morgan et al., 2013). However, the inability of interventions to demonstrate lasting results may not stem from the methodology alone, but rather the participants themselves. While understanding how physically active children are is important, we should also be asking if typically developing children are performing gross motor skills at age-appropriate levels.

Data show that boys and girls differ in basic motor skills proficiency. Results from several studies reveal that boys have greater object control (kick, catch and overhand throw) than girls (Barnett, van Beurden, Morgan, Brooks, & Beard, 2008, 2010; LeGear et al., 2012). Childhood object control (by either gender) predicted adolescent cardio respiratory fitness (Barnett, van Beurden, et al., 2008) and was positively associated with perceived sport competence (Barnett, Morgan, et al., 2008). However, the differences between boys' and girls' locomotor skills (hop, side gallop, dodge, vertical jump and leap) are inconclusive with some researchers reporting differences (Barnett, Morgan, et al., 2008; Hardy, King, Farrell, Macniven, & Howlett, 2010; Robinson, 2011) while others report none (Barnett et al., 2010; Okely & Booth, 2004).

Differences in FMS proficiency also exist between children of healthy weight and those who are overweight or obese, with the former performing better (D'Hondt et al., 2011; Poulsen et al., 2011). Weight affects individual FMS differently: skills such as hopping, which require the body to be moved quickly and against gravity, are more likely to be impacted by an increased BMI (D'Hondt et al., 2011). Overweight children demonstrated poorer self-concept perceptions regarding physical abilities (Poulsen et al., 2011), which, as previously stated, further compromises a child's desire to be physically active (Wall, 2004).

The objective of this study was to investigate the gross motor competencies of a wide age range (4 to 15 years) of typically developing children in a large Western-Canadian city. Specifically, does a sample of Canadian children fall within the established American norms? Gross motor skills involve the use of the large muscle groups and whole-body movement and are more relevant to the PE classroom than fine motor skills. Furthermore, selecting just the gross motor subtests significantly reduced the testing time, making it more appealing for community-based research. This research has the potential to help us understand the level at which children are at in their gross motor development (GMD), and therefore be able to inform current practice in school and community PA programming.

Method

Participants

Recruitment took place from 2011-2013 and testing took place from 2011-2015 in Calgary, Alberta, Canada. Participants were a convenience sample of 589 children between the ages of 4-15; 54% were boys (see Table 1). We recruited children from three locations: the largest public charter school district in Canada (grades K-12, representing 71 communities within the city), a university daycare centre and a public regional recreation facility with over 1 million user visits annually. Recruitment strategies varied by location. Age categories are unequal due to a representation by school division: preschool (ages 4-5), elementary school (grades K-4; ages 6-9), and middle school (grades 5-9; ages 10-15).

A pre-established research partnership existed between the Mount Royal University's (MRU) Health and Physical Education Department (HPED) and both the charter school district and the recreation facility; therefore, external administrators were familiar with recruitment and research procedures. In 2011, we sent letters home seeking consent to participate to all parents of grade 4 students. In 2012, we sent consent letters to new grade 5 students (not in the previous cohort), and in 2013, we sent consent letters to new grade 6 students. Ninety-eight percent of parents consented to allow their child(ren) to participate.

We recruited preschool-aged children attending the MRU daycare and recreational centre preschool via letters sent home to parents in 2012. General recruitment at the recreation facility took place on six separate occasions in 2012, at various times throughout the day in an attempt to reach the largest number and variety of participants. Recruiters set up information booths at community events near the recreation facility where parents/guardians of children could sign-up to participate in the study or take study information home. Inclusion criteria stated that children must be healthy and free from diagnosed orthopedic, neurologic, or developmental conditions that could create motor proficiency or PA impairments (as determined by a written questionnaire screening completed by parents). The Human Research Ethics Board at MRU granted ethical approval.

Table 1
Demographic Data for Children Participating in Gross Motor Testing

Gender (N=589)	n (%)
Female	273 (46.4)
Male	316 (53.6)
Age (N=589)	
4-5 years	148 (25.1)
6-9 years	164 (27.8)
10-15 years	277 (47.0)
BMI Category (N=577)	
Risk for underweight (<3rd percentile)	14 (2.4)
Healthy weight (3rd to <85th percentile)	422 (73.1)
Risk for overweight (under age 5 only; 85th to 97th percentile)	19 (3.3)
Overweight (ages 5-15; 85th to 97th percentile)	104 (18.0)
Obese (>97th percentile, ages 5-15; >99th percentile under age 5)	18 (3.1)
BMI-percentile (N=577)	Median (IQR)
	58.0 (31.0-84.0)
BMI Z-score (N=577)	Mean (SD)
	0.26 (1.12)

Measurement

Anthropometrics. We measured weight and height for each child. Children wore light-weight gym clothing (shorts and t-shirt); shoes were removed. Weight was measured in kilograms to the nearest tenth using a Tanita Body Fat Monitor for Children (Model BF-689) calibrated prior to each participant. Standing height was measured in centimeters to the nearest hundredth using a stadiometer (Seca 213). We calculated each participant's BMI using his or her height, weight, age and gender. The WHO standards (World Health Organization, 2006, 2007) were used which divide children into two categories: ages 2 to 4 years 11 months and 5 to 19 years.

Gross Motor Development. The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2; Bruininks & Bruininks, 2005) was used to assess children's gross motor ability. The BOT-2 was validated on 1,520 American children ages 4-21 years, random and stratified across sex, race/ethnicity, socioeconomic status, and disability status in each age group. Four administration options are available: the Complete Form, the Short Form, select Composites or select Subtests. For this study we selected only the gross motor tests, which include Upper-Limb Coordination, Bilateral Co-ordination, Balance, Running Speed & Agility, and Strength (see Table 2 for the skills tested in each category). Internal consistency for children ages 4-15 on these subtests ranges from 0.60-0.93, with the majority ranging from the high 0.70s to the low 0.80s. Test-retest reliability on the full scale ranges from 0.80 (13-21 year olds) to 0.88 (4-7 year olds). Inter-rater reliability correlations for all ages range from 0.86-0.99. Scale scores adjusted for child age and gender were used to interpret test performance. Scale scores range from 1-35, and are standardized to a mean of 15 with a standard deviation of 5. A scale score of 25 or greater indicates well-above average skill; 20-24 is above average; 11-19 is average; 6-10 is below average; and 5 or less indicates well-below average skill.

Table 2
BOT-2 Gross Motor Skills Subtests and the Corresponding Items Measured

Gross Motor Subtest	Skills Tested
Upper-Limb Coordination: measures visual tracking with coordinated arm and hand movements.	• Dropping and catching a ball, one hand/two hands • Catching a tossed ball, one hand/two hands • Dribbling a ball, one hand/ alternating hands • Throwing a ball at a target
Bilateral Co-ordination: measures body control, sequential and simultaneous coordination of the upper and lower limbs.	• Touching fingertips to nose, eyes closed • Jumping jacks • Stride jumps; same side/opposite side synched • Pivoting thumb and index finger (as in "itsy bitsy spider") • Tapping feet and fingers, same side/opposite side synched
Balance: measures stability of the trunk, stasis and movement, and use of visual cues.	• Standing on both feet on a line with eyes open/closed • Walking forward on a line • Standing on one foot on a line with eyes open/closed • Walking forward/standing on a line, heel-to-toe • Standing on one leg on a balance beam with eyes open/closed
Running Speed & Agility:	• Shuttle run • Stepping sideways over a balance beam • One-legged stationary hop • One-legged/two-legged side hop
Strength: measures trunk, upper and lower body strength.	• Standing long jump • Push-ups (full or modified) • Sit-ups • Wall sits • V-up (laying on stomach with arms outstretched, lifting feet and shoulders off the floor)

Procedure

An occupational therapist well versed in the administration of the BOT-2 trained the research assistants (RAs) in the administration of the BOT-2. Training videos were used initially and annually as a refresher prior to testing each spring. Administration of the BOT-2 is scripted and all necessary scripts and equipment are provided in the test kit. Inter-rater reliability was tested at regular intervals and remained above $\alpha = 0.80$.

Research assistants conducted gross motor testing at three different locations, depending on where recruitment took place. At the schools, two RAs removed students from their regular classes in pairs. Testing was conducted individually in either a multi-purpose room or the stage of the gymnasium with the curtain drawn. Research assistants conducted testing on daycare children in the MRU HPED Physical Literacy Research Lab. Preschool children had a parent present. Research assistants tested children recruited in the recreation centre in the dedicated research space provided to MRU HPED staff by the facility. Research assistants set up the evaluation area prior to bringing the participants in for testing. Testing took approximately 30-45 minutes per child. Testing followed the same order with each child: balance, upper limb coordination, strength, running speed & agility and bilateral coordination.

Analysis

Research assistants transcribed record-sheet data from the testing sites into the BOT-2 Assist software. Aggregate data for each individual were exported to Excel and the necessary variables then exported to Stata Version 13.0 (StataCorp LP, College Station, TX, USA) for analysis. Descriptive statistics were conducted on demographic variables (gender, age category, BMI) using frequencies and percentages. The Pearson's Chi-Squared test was used to examine differences between these three variables where $p < 0.05$ was considered statistically significant.

Table 3 reports the scale score means and standard deviations on the five gross motor subscales (upper limb coordination, bilateral coordination, balance, running speed & agility, and strength). The 95% confidence interval for the mean is provided for comparison between our sample and the standardized mean score of 15. Scale scores are categorized into the descriptive categories as outlined in the BOT-2 manual and reported as frequencies and percentages.

Univariate analyses using the two-sample T-test (or ANOVA for more than two categories) were conducted in which gender (male, female), age (4-5 years, 6-9 years, 10-15 years), and BMI (≤85th percentile, >85th percentile) were examined as potential categorical predictors for each of the five gross motor scale scores. If a predictor was significant at $p <$ 0.10 for any of the outcome measures, it was considered eligible for multivariable modeling. An interactive approach was used in the multivariable modeling process for each of the five gross motor outcomes. The possibility of interaction between the predictor variables was first examined and assessed using the Likelihood Ratio Statistic in the model evaluated at $p <$ 0.05. After determining that no interaction existed in any of the five models, variables were included and retained as individual predictors in each model if they were eligible during the univariate stage.

Results

BOT-2 norms were used in this study for comparative purposes. The norms are based on the 2001 U.S. Current Population Survey and data from the Twenty–sixth Annual Report to Congress (Bruininks & Bruininks, 2005). Sample selection was random and stratified among four racial/ethnic groups and four geographical regions (Northeast, North Central, South and West) as described by U.S Census Bureau. The sample consisted of 1,520 participants between the ages of 4 to 21 years, and testing was done at 239 sites in the 28 states (Bruininks & Bruininks, 2005).

The majority of gross motor skills testing took place from 2012-14 (81.5%). Table 1 presents the demographic data. Children ranged in age from 4-15 years old, with the majority falling into the 10-15 year old category (47%). BMI was calculated for 577 participants. The majority of participants were of normal weight (>3rd to <85th percentile; n = 422, 73%). Since only 2% (n = 14) of participants were at risk for underweight (<3rd percentile), this category was combined with normal weight for analysis (n = 436). Similarly, the at-risk for overweight participants under the age of 5 (85th to 97th percentile; n = 19, 3%) were combined with overweight (85th to 97th percentile; n = 104, 18%) and the obese children (>97th percentile; n=18, 3%) for a total of 141 children (24%). No statistical difference existed between BMI and gender with 21.4% of females and 27.0% of males having a BMI above the 85th percentile (Chi-Square = 2.42; $p = 0.12$). A statistical difference did exist for BMI and age with the middle age group having the lowest BMI (Chi-Square = 7.45; $p = 0.024$). In the youngest group, 24.5% had a BMI greater than the 85th percentile, 17.2% in the middle age group and 28.8% in the oldest group.

Table 3 presents the scores from the five gross motor subscales. As a group, participants were within the normal range for gross motor development (scale score range 11-19). However, two tests, upper limb coordination (M = 13.5; 95% CI = 13.2, 13.9) and balance (M = 14.3; 95% CI = 13.9, 14.6), failed to meet the average scale score (15). Despite this, 62% and 65% of children, respectively, were "average" in the descriptive categories. As would be expected, these two categories had the highest number of participants scoring in the below or well-below average (28% and 22% respectively). Bilateral coordination (M = 17.1, 95% CI = 16.8,17.5) and running speed & agility (M = 16.8, 95% CI = 16.5,17.1) showed the best results, with 36% and 22% children, respectively, scoring in the above or well-able average categories.

Table 3
BOT-2 Scale Scores and Descriptive Categories for the Overall Sample (N=589)

	BOT-2 Scale Score		BOT-2 Descriptive Category		
	Mean (sd)	95% CI	Above / Well Above Average n (%)	Average n (%)	Below / Well Below Average n (%)
Upper Limb (N=580)	13.5 (4.3)	13.2-13.9	59 (10.2%)	361 (62.2%)	160 (27.6%)
Bilateral Coordination (N=582)	17.1 (3.9)	16.8-17.5	210 (36.1%)	340 (58.4%)	32 (5.5%)
Balance (N=581)	14.3 (4.6)	13.9-14.6	79 (13.6%)	376 (64.7%)	126 (21.7%)
Running Speed & Agility (N=581)	16.8 (3.8)	16.5-17.1	130 (22.4%)	417 (71.8%)	34 (5.9%)
Strength (N=582)	15.5 (3.9)	15.2-15.9	87 (15.0%)	442 (76.0%)	53 (9.1%)

Table 4 shows the bivariate analyses that examine the effects of BMI, age and gender on gross motor skills. BMI was associated with balance ($p = 0.013$), running speed & agility ($p < 0.001$) and strength ($p < 0.001$). Age was associated with all five subtests (all $p < 0.05$) and gender was not associated with any, excluding it from further analysis.

Table 4

Univariate Analysis of BOT-2 Subscales by BMI, Age, and Gender

	BMI Category			Age Category				Gender		
Subscale	At or below the 85th percentile N=436 Mean (sd)	Above the 85th percentile N=141 Mean (sd)	P	4-5 years N=148 Mean (sd)	6-9 years N=164 Mean (sd)	10-15 years N=277 Mean (sd)	p	Female N=273 Mean (sd)	Male N=316 Mean (sd)	p
Upper Limb	13.5 (4.3)	13.8 (4.3)	0.499	12.9 (3.8)	13.3 (4.6)	14.0 (4.3)	0.028	13.4 (4.4)	13.6 (4.2)	0.617
Bilateral Coordination	17.3 (3.7)	17.0 (4.3)	0.457	18.0 (4.1)	17.3 (4.0)	16.6 (3.6)	0.002	17.2 (4.0)	17.1 (3.7)	0.625
Balance	14.5 (4.6)	13.4 (4.4)	0.013	13.7 (4.3)	14.0 (4.9)	14.7 (4.4)	0.051	14.3 (4.6)	14.2 (4.5)	0.810
Running Speed & Agility	17.2 (3.8)	15.6 (3.6)	<0.001	16.1 (4.1)	17.3 (4.0)	16.9 (3.4)	0.017	17.0 (4.0)	16.6 (3.6)	0.147
Strength	15.9 (3.8)	14.6 (4.2)	<0.001	15.9 (3.8)	16.1 (4.6)	15.0 (3.5)	0.011	15.5 (3.8)	15.5 (4.1)	0.971

Table 5 and Figure 1 show the numerical and graphical results of the multivariable modeling where both BMI and age were significant, independent predictors of gross motor ability. To summarize using the youngest participants as the comparison group, the oldest participants performed better on upper limb coordination (Coef = 1.28; SE=0.44; 95% CI = 0.41, 2.15), and lower on bilateral coordination (Coef=-1.29; SE=0.40; 95% CI =-2.07,-0.51), both regardless of BMI. Figure 1 provides a visual depiction with the upward and downward trend on the corresponding plots. Children who scored above the 85th percentile for weight showed lower balance scores (Coef = -1.23; SE = 0.44; 95% CI = -2.1,-0.35), running speed & agility (Coef = -1.57; SE = 0.36; 95% CI = -2.29,-0.86), and strength (Coef = -1.25; SE = 0.38; 95% CI = -2.0,-0.5) scores when compared to their normal weight counterparts, regardless of age. Figure 1 illustrates the gap in scores between the two BMI categories for each of these three subscales. Oldest participants performed higher on balance, but lower on strength compared to the youngest participants; middle and oldest participants performed better in running speed & agility compared to the youngest, independent of BMI (Table 5; Figure 1).

Table 5

Multivariable Modeling for each BOT-2 Subscale including BMI and Age as Predictor

BOT-2 Scale	Coef	SE	T	P	95% CI
Upper Limb Coordination					
BMI Category					
Below 85th percentile	Ref				
Above 85th percentile	0.18	0.42	0.44	0.661	-0.64, 1.00
Age					
4-5 years	Ref				
6-9 years	0.42	0.49	0.86	0.388	-0.54, 1.39
10-15 years	1.28	0.44	2.88	0.004	0.41, 2.15
Bilateral Coordination					
BMI Category					
Below 85th percentile	Ref				
Above 85th percentile	-0.22	0.38	-0.57	0.566	-0.95, 0.52
Age					
4-5 years	Ref				
6-9 years	-0.71	0.44	-1.60	0.110	-1.57, -0.16
10-15 years	-1.29	0.40	-3.24	0.001	-2.07, -0.51
Balance					
BMI Category					
Below 85th percentile	Ref				
Above 85th percentile	-1.23	0.44	-2.76	0.006	-2.10, -0.35
Age					
4-5 years	Ref				
6-9 years	0.19	0.52	0.36	0.716	-0.83, 1.21
10-15 years	1.21	0.47	2.57	0.010	0.29, 2.14

Running Speed & Agility					
BMI Category					
Below 85th percentile	Ref				
Above 85th percentile	-1.57	0.36	-4.34	<0.001	-2.29, -0.86
Age					
4-5 years	Ref				
6-9 years	1.14	0.43	2.66	0.008	0.30, 1.98
10-15 years	0.91	0.39	2.36	0.019	0.15, 1.67
Strength					
BMI Category					
Below 85th percentile	Ref				
Above 85th percentile	-1.25	0.38	-3.27	0.001	-2.00, -0.50
Age					
4-5 years	Ref				
6-9 years	0.04	0.45	0.09	0.927	-0.84, 0.92
10-15 years	-0.80	0.41	-1.98	0.049	-1.60, -0.01

Ref = Reference Group

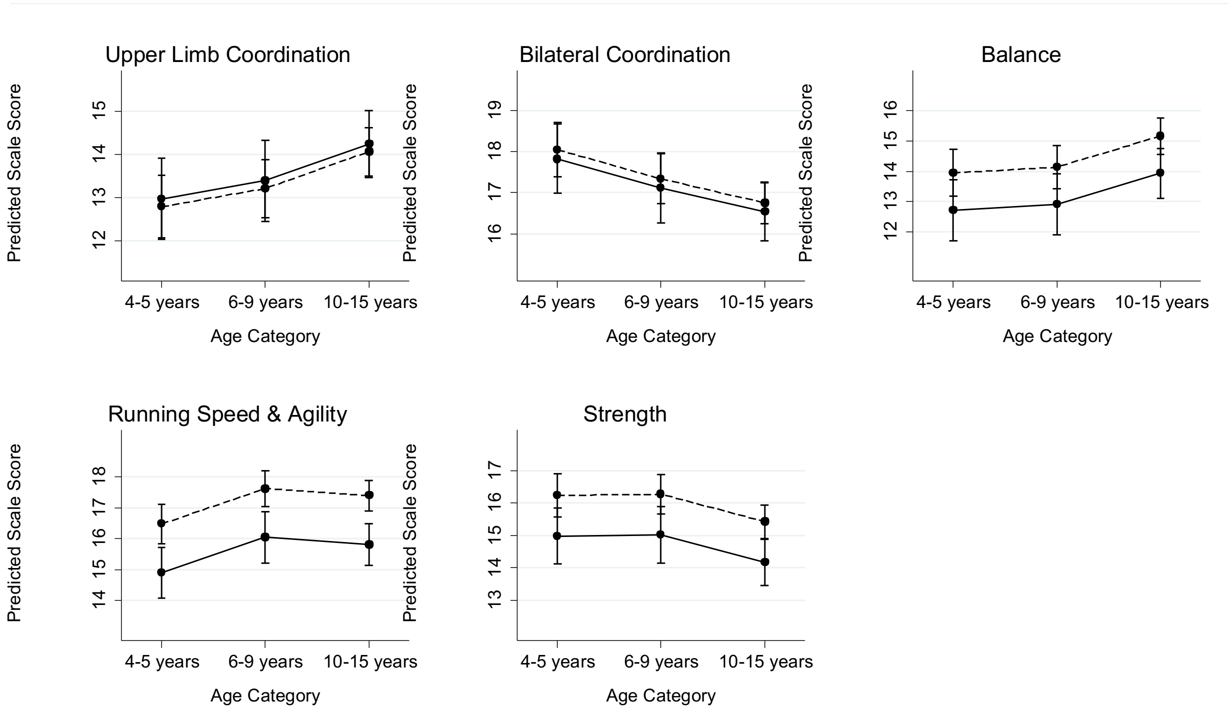

Figure 1. Predicted Mean Score (95% CI) for each BOT-2 Subscale, by BMI Category. A hashed line represents below the 85th percentile; a solid line represents above the 85th percentile.

Discussion

Our study aimed to understand the gross motor development of a wide age range (4-15 years) of typically developing Canadian children using the BOT-2 (Bruininks & Bruininks, 2005). Recent small (Bremer & Lloyd, 2014), and age-limited (LeGear et al., 2012) Canadian studies reveal that FMS are lacking in children. Research from several countries indicates the same results (Erwin & Castelli, 2008; Okely & Booth, 2004; Spessato, Gabbard, Valentini, & Rudisill, 2013). Reviews of FMS studies do not include any Canadian studies (Morgan et al., 2013; Riethmuller, Jones, & Okely, 2009) demonstrating a gap in the literature. By understanding where typically developing Canadian children place according to established standards of gross motor development, PA planners, educators and other stakeholders can create appropriate and adaptable programs and interventions to meet the needs of children. In other words, physical activity programming could be tailored based on results from gross motor domains evaluated among Canadian children. This information will give practitioners a better understanding of how Canadian children compare to the norm, and what gross motor domains need specialized programming.

As a group, children in our study scored within the average scale score range (11-19) on all gross motor skills as tested by the BOT-2 (Bruininks & Bruininks, 2005), and therefore meet the expectations for gross motor FMS development. Bilateral coordination was the strongest subtest (scale score 17.1) and upper limb coordination was the weakest subtest (13.5). Although upper limb coordination appears to have a low score (below the mean of 15), fully 72% of children were still either average, above average or well above average in this domain. Our results are in contrast to the recent Canadian and international studies cited above reporting that children are not meeting the age-appropriate FMS standards (Bremer & Lloyd, 2014; LeGear et al., 2012; Erwin & Castelli, 2008; Okely & Booth, 2004; Spessato, Gabbard, Valentini, & Rudisill, 2013).

Data from 2,123 Canadian children ages 5 to 17 years indicate that 19.8% are overweight and 11.7% are obese (Roberts, Shields, de Groh, Aziz, & Gilbert, 2012). Eighteen percent of our 5 to 15 year olds were overweight and only 3% of all participants were obese, which follows the trend highlighted in the Alberta report (Alberta Health Services, 2010). BMI increased with age in our sample, which is typical of Albertan and Canadian children. National data indicate that 12 to 17 year olds are more likely to be overweight and obese than 5 to 11 year olds (37% vs. 26%; Statistics Canada, 2014). Provincial data indicate the same: 12-17 year olds have a combined overweight and obesity rate of 30.3% compared to 16.1% in 2-11 year olds (Alberta Health Services, 2010). Similarly, boys and girls both in our study and in the national sample are equally likely to be overweight; however, in the national sample boys are more likely to be obese than girls (Statistics Canada, 2014), a trend not found in our study.

We noticed that children in our study with a BMI in excess of the 85^{th} percentile demonstrated poorer balance, running speed & agility and strength scores. The negative relationship between excessive BMI and the physical skills of children and adolescents has been widely studied (Bryant, Duncan, & Birch, 2014; Castetbon & Andreyeva, 2012; Cliff et al., 2012). Obesity alters musculoskeletal structure and function even in very young children (Wearing, Hennig, Byrne, Steele, & Hills, 2006) thus affecting locomotor FMS. For example, gait initiation in obese adolescents is slower as it is harder to increase the inertial mass to commence movement and harder to control the dynamic balance resulting in slower movement (Colné, Frelut, Peres, & Thoumie, 2008). Deforche et al. (2009) similarly found that overweight boys performed tasks such as walking on a line and sit-to-stand tests more slowly. Colné et al. (2008) suggest that a slower speed in obese adolescents could be a form of self-preservation: they are attempting to limit the risk of falling by shortening the phase of disequilibrium. Obese children demonstrate a wider step width indicating a broader base of support, which suggests poorer postural stability (Deforche et al., 2009). In their test of heel-to-toe walking where the base of support was minimized, overweight boys compensated by walking more slowly than normal weight boys (Deforche et al., 2009) and in general demonstrated poorer balance than the normal weight participants (Goulding, Jones, Taylor, Piggot, & Taylor, 2003).

The musculoskeletal requirements for running, jumping and hopping are such that it is more common for overweight and obese children to demonstrate lower locomotor skills than object control skills, which are more static in nature (Castetbon & Andreyeva, 2012; Hardy, Reinten-Reynolds, Espinel, Zask, & Okely, 2012; Okely, Booth, & Chey, 2004; Wearing et al., 2006). Much like in our study where BMI did not affect upper-limb coordination or bilateral coordination, Okely et al. (2004) found that normal weight children were two to four times more likely to be proficient in locomotor skills, but showed no difference in object-control skills. Better proficiency in object control versus locomotor skills is not universal. In a study of 12 FMS, Cliff and colleagues (2012) report that 18 of 24 locomotor skills components and 19 (ages 6-7) and 21 (ages 8-10) of 24 object control skill components scored significantly lower in overweight/obese children as compared to the reference sample of normal weight children. They also found that several components of each FMS scored lower than other components, specifically: body and/or foot positioning, controlling or releasing the object in an optimal position, use of the arms to maintain effective force production, bending the knees to lower the body, and hip rotation to generate force (Cliff et al., 2012). It appears as though many of the components of skills where children fall short are similar to those that affect locomotor skills, most notably those pertaining to balance and positioning.

Bigger children are generally stronger than smaller children (De Ste Croix, Deighan, & Armstrong, 2003) due to their greater mass and size advantage, thus we could expect that the participants in our study with a higher BMI would score better on strength than those with a lower BMI. This, however, is offset by the fact that field tests for strength generally require the resistance or movement of the individual's body mass (such as pull-ups), placing children with a large body mass at a disadvantage (De Ste Croix, 2007; Milliken, Faigenbaum, Loud, & Westcott, 2008). In a study of tests of strength between obese and non-obese children, the former performed significantly better on upper limb tests (i.e., throwing distance), but significantly less on lower limb tests (i.e., jumping and rising from a chair) than the latter (Riddiford-Harland, Steele, & Baur, 2006).

Due to the cross-sectional nature of this study, we cannot infer causality of poorer gross motor skills in overweight and obese children: whether excess adipose tissue causes poor gross motor skills, or poor gross motor skills causes excess adipose tissue, is unknown from our data. Differences between normal weight and overweight children at a young age are a concern as BMI tends to increase with age (Statistics Canada, 2014) and PA levels tend to drop, especially with girls (Trost, Pate, & Sallis, 2002).

No gender effects were apparent in this study; however, scale scores were adjusted for gender and we did not analyze the comparative raw scores between genders. Numerous studies have found differences between boys' and girls' motor skills before adjusting for gender.

Although within the normal range, children in the present study had lower scores in upper limb coordination and balance. In a study of grades four and five children assessed according to the National Association for Sport and Physical Education (NASPE) standards (NASPE, 2004), researchers found that only 42% achieved a score of "competence" in dribbling and passing a basketball and 56% were competent at throwing a ball (skills used to determine upper limb coordination; Erwin & Castelli, 2008). Morgan et al. (2013) suggest that object control skills may be harder to improve than locomotor skills due to greater skill complexity. This indicates an even greater need to begin teaching these skills at a younger age with an intentionally designed program based on developmental scope and sequence. The emphasis here is placed on *teaching*, as solely providing opportunities for free play is not sufficient for the development of FMS (Hardy et al., 2012). The skills of children in PE classes with teachers who prompted and encouraged activity more often were better than those who did not receive the positive feedback (McKenzie, Alcaraz, Sallis, & Faucette, 1998). A balance of purposeful instruction and unstructured free play may be most beneficial for children given their natural propensity toward movement (Sheehan & Katz, 2011).

Teaching is not limited to those within the school system; parents can also facilitate FMS development. Enlisting parents to improve FMS is not only beneficial for skill development, but is also important in creating an appreciation for being active. Children who see their parents participating in PA and who are supported by their parents in the choice to be physically active, demonstrate higher levels of PA (Sallis, Prochaska, & Taylor, 2000). Okely and colleagues (2004) recommend that FMS be focused on at a young age, when children are keen to develop skills, have not yet developed bad habits, and before severe deficits present (Barnett et al., 2010).

In the current study, age was significantly correlated with all gross motor subtests. This finding is in contrast to what we would expect, as the subscales are adjusted for age. This indicates that some children are scoring higher or lower than what we would anticipate for their age.

The decrease in strength scores with age is contrary to what we would expect. A linear relationship exists between strength and age until the onset of puberty in boys (approximately 13 years old) and the end of puberty in girls (approximately 15 years in girls; De Ste Croix, 2007). Since strength should be proportional to muscle cross-sectional area, size matters; and indeed, increases in stature and body mass both independently affect strength (De Ste Croix, Armstrong, Welsman, & Sharpe, 2002). Numerous studies report that regardless of gender, older children demonstrate greater strength than younger children do (Schneider, Benetti, & Meyer, 2004; Wood, Dixon, Grant, & Armstrong, 2004). Only one study was located reporting that as girls aged, bicep strength decreased (Round, 1999). A possible explanation for this difference is that our sample may represent stronger 'young' and 'middle' age group children as their results are above average, whereas the 'oldest' children's strength scores are exactly average.

An early study of FMS found that the overhand throw, a component of upper limb coordination, was not mature in 60% of participants until age 63 months (5.25 years) for boys and 102 months (8.5 years) for girls (Branta, Haubenstricker, & Seefeldt, 1984). A study of short- and long-distance ball catching also found that the results improved with age (Van Waelvelde, De Weerdt, De Cock, & Engelsman, 2003). Both of these studies support our data, where upper limb coordination improved significantly with age.

Bilateral coordination, too, should improve with age. For example, Magalhaes et al. (1989) indicate that jumping jacks should not be expected before the age of 7 years. In their, albeit small (10 boys and 10 girls) pilot study, by nine years of age, 50% of children were achieving the symmetrical stride jump and only 15% of that age group achieved the asymmetrical stride jump (Magalhaes et al., 1989). Although the children in our study did well in this domain, bilateral coordination was best in the youngest group and decreased significantly with age.

Limitations

Children often perform well on one occasion and poorly on another. This may be due, in part, to body changes (size and proportion), neuromuscular maturation, opportunity for practice, motivation, unknown adults administering the test and desire to cooperate (Malina, 2004). The cross-sectional nature of this study does not allow us to determine if the children were having a “good” or “bad day.”

Self-selection bias may be present in our study. Since overweight and obese children may resist participating in PA because they do not enjoy it (Faith, Leone, Ayers, Heo, & Pietrobelli, 2002), are concerned about others seeing their bodies while active (Zabinski, Saelens, Stein, Hayden-Wade, & Wilfley, 2003), or may not be successful at completing tasks (Poulsen et al., 2011), they may have chosen not to participate in the study. This would likely only affect those recruited from the recreation centre and the community events since enrolment in the study at these locations required the child to express interest in the study to receive information about it (all children at the schools were invited to participate without regard for weight status). However, there is a possibility that some parents refused consent on behalf of their children. Parents of overweight children may not provide as much encouragement to participate in PA, as do parents of normal weight children (Zabinski et al., 2003). Parents may also perceive their overweight or obese children as having lower PA skills (Davison & Birch, 2001) and may wish to spare them the stress of the study or the direct confirmation that their children do not possess adequate gross motor skills. Due to the nature of the convenience sample, the results presented may not be generalizable to a broader population.

Conclusion

Gross motor skills testing revealed that the children in our study are within the average range for FMS development. Upper limb coordination and balance are the two skills that could benefit from the attention of PE teachers, program planners and parents as scores were just below the desired mean.

There has been an increased emphasis in Canada on the importance of FMS, largely due to the physical literacy movement lead by the sport sector. Canada's long-term athlete development program (LTAD) places a significant emphasis on the development of motor proficiency in the early years. This national initiative has influenced sectors outside of sport, including education and recreation, to place a greater importance on movement fundamentals in an effort to build greater competence and confidence in young Canadians. Measuring outcomes objectively, as presented in this study, will be important for evaluating successes of future Canadian FMS programming. This study can serve as a baseline for other researchers studying motor proficiency in children and youth.

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